Land-Use and Travel Behaviour. A Survey of Some Analysis and Policy Perspectives

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This paper discusses interactions between land-use and travel behaviour in the light of recent developments on the policy arena, in particular the increasing emphasis on sustainable development of urban and regional systems. Schemes for integrated analyses of land-use and transport and for comparing urban structures in terms of land-use dispersion and travel behaviour are presented. The new national transport policy of Sweden has a strong emphasis on environmental and safety objectives. However, increasing vehicle kilometres of travel (VKT) and decreasing transit shares are characteristic for the projected development of Stockholm until the year 2030. Only very drastic integrated policies can reduce VKT to a level consistent with long-term environmental targets. Land-use policies play a small role in this context. A transit-oriented settlement structure on the sub-regional scale tends to be more important than increased density on the regional scale. Compact cities and local job-housing balance may provide the potential for sustainable transport behaviour, but other policies and strong incentives are needed to reverse current urban development trends. With current trends other urban forms (e.g. "decentralised concentration" or "corridor development") are likely to be more efficient in terms of VKT.

1. Introduction

The discussion of linkages between land-use and transport on the urban level and between regional development and transport on the interregional level has been intensive in many

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countries during the recent decades. The increasing importance of environmental issues has been confronted with rapidly growing volumes of person transport and freight. The growth of the globalising economy and the deregulations and reductions of barriers in the European context have resulted in increasing transport of goods and people over longer distances.

On the urban scale consistent trends towards higher volumes of car traffic and decreasing transit shares have emerged. From partial equilibrium models of simple mono-centric urban economies we learn that increased income, a growing population and more efficient means of transport all lead to expanding urban areas, lower densities and longer transport distances. Other factors like increased specialisation on the labour market and increasing labour participation rates tend to reinforce the observed tendencies towards increased volumes of car traffic.

The interest in policies for a sustainable development during the 1990s has focussed on the need for systematic and system-wide measures that reconcile ambitions concerning economic growth, social equity and environmental protection. Hence, the interactions between spatial development and transport behaviour should be seen in the light of emerging policies for sustainability. Part of this paper is based on sections in Lundqvist (2000) and Lundqvist (2003).

This paper is organised in the following way. First a short review of land-use/transport interactions is provided in Section 2 together with some observations on the development of the policy context (mainly in Sweden) and on implications for modelling. Results from applications of transport models and land-use/transport models in Stockholm are summarised in Section 3. The focus is on illuminating relations between land-use and travel behaviour. In Section 4 results from similar studies in other spatial contexts are presented. Section 5 contains Swedish and international perspectives on interactions between transport, land-use and regional development. Finally, the main conclusions from the paper are outlined in Section 6.

2. Interactions between land-use and travel behaviour in the light of policy developments: some implications for modelling

Land-use and transport systems are, in principle, interdependent. Strong arguments support the proposition that different urban forms and different land-use patterns (density, mix) influence the conditions for various transport systems and lead to different transport and travel patterns. Similarly, strong reasons can be stated for the potential influence of transport supply on location decisions of firms and individuals and in the long term also on the settlement structure. However, it should be emphasised that these seemingly natural and mutual interactions do occur with different speeds and with various delays. Land-use/transport interactions are also masked by many other mega trends and socio-economic developments (e.g. demographic, economic, social, policy-making) with potential (stronger or weaker) linkages to the land-use/transport systems. Wegener (1996) summarises these mutual interactions in “the land-use transport feedback cycle”. Another way of illustrating the linkages between land-use and transport is shown in Figure 1.

It should be clear that the time scales of various impacts in Figure 1 are widely different: from more or less daily route and mode choices, to intermediate time horizon changes of location (moves), car ownership, travel patterns, traffic management and transit supply to very long term changes of transport network design, urban form and settlement structure. There are obvious feedback loops within and between the land-use and transport markets providing strong reasons for integrated modelling and policy analysis of land-use/transport systems.

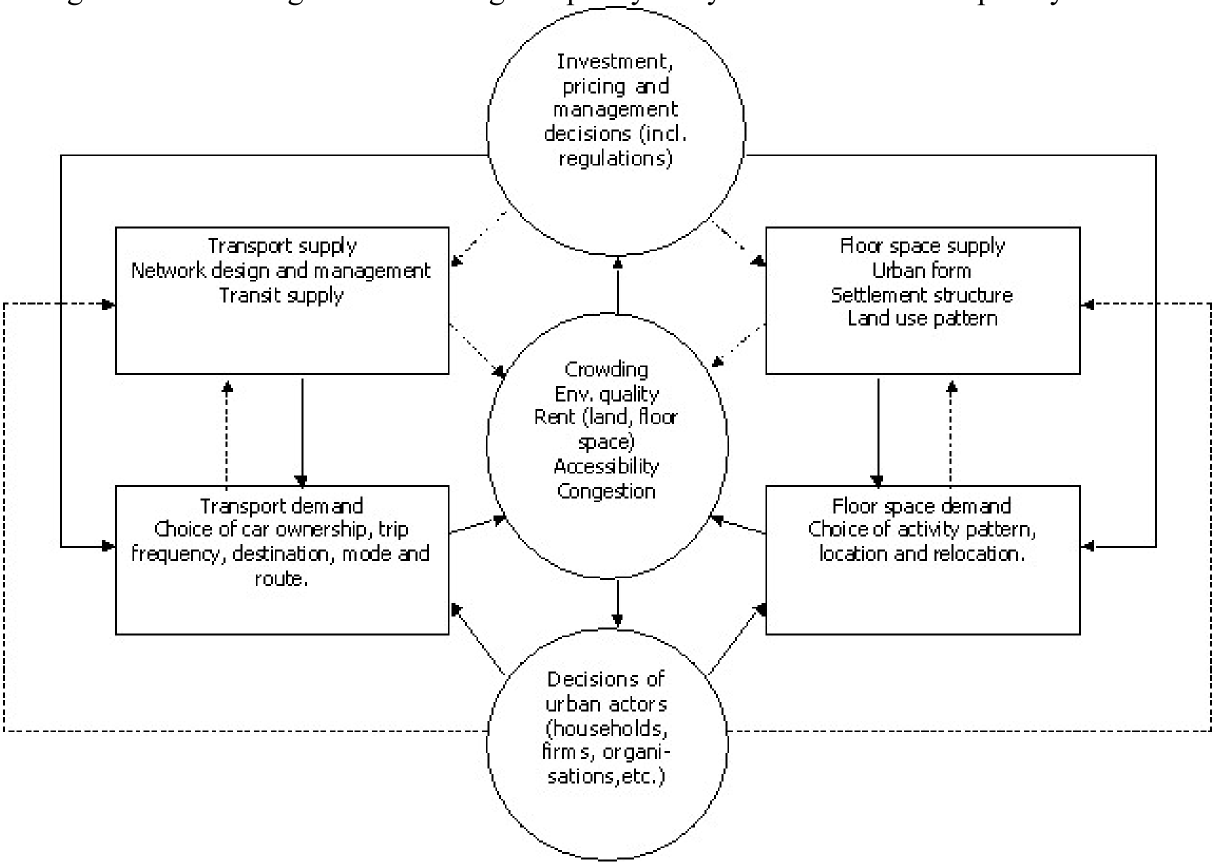

Figure 1. Linkages between the transportation market and the land-use market (dotted arrow: medium to long-term impacts; solid arrow: short to medium-term impacts).

Another way of illustrating some fundamental relationships between land-use and transport behaviour is the "Brotchie triangle". A simplified version is shown in Figure 2. In a very stylised way, any urban structure is characterised in two dimensions: one indicator of spatial interaction (e.g. average trip length or travel time) and one indicator of dispersal of non-residential land-use (e.g. degree of decentralisation of working places). After defining proper indicators for these two dimensions, any urban region can be represented as a point in the diagram at any point of time (e.g. D). Different urban regions can be compared with each other at any point of time and the development over time of any urban region can be represented as a trajectory in the diagram (e.g. D → E). It is instructive to think of a circular and symmetric city with residents distributed around the geographical centre. Spatial interaction is measured in terms of the average trip length for commuting. Point A in Figure 2 represents the case where all employment activities are located in the city centre. All commuters have to travel to the centre (many-to-one interaction) and the average trip length can be uniquely defined. Radial transport systems and mass transit constitute relevant options in such a context. At the other extreme, along the axis B-C employment has the same spatial distribution as residential location (i.e. “complete” decentralisation). In this case, the trip length depends heavily on travel behaviour: if residents choose the nearest employment opportunity, point C would be the result with very short local trip length, while if residents choose employment opportunities at random, point B would be the result with very long average trip length. Point C would reflect one-to-one interaction on local networks while point B corresponds to many-to-many interactions with dispersed traffic flows on complete networks. Different kinds of socio-economic scenario assumptions and technological developments can be related to various parts of the diagram. A few examples are indicated in Figure 2. The prevailing development trend can be represented as a trajectory in the “eastern” or “north-eastern” directions (like D → E): towards more decentralisation of employment, more car traffic and tendencies towards longer trip lengths in more dispersed travel patterns.

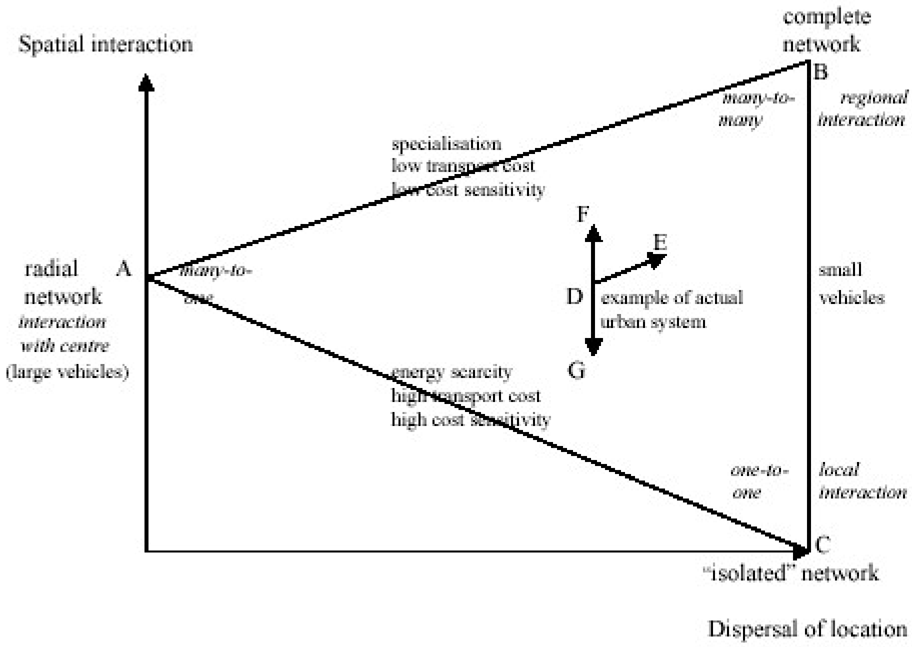

Figure 2. Main features of the “Brotchie triangle” on land-use and travel behaviour. For a more complete original figure and discussion, see Brotchie (1984).

Land-use/transport modelling has developed since the 1960s but mainly in research environments or pilot projects. The criticism of Lee (1973) had strong influences both on the modelling field and on attitudes of practitioners towards modelling. Large-scale urban models were accused for e.g. being data hungry, non-transparent and computer intensive. Some of these objections have become less relevant due to developments of theories, modelling techniques, statistical estimation methods, computing capability, etc (see Lee (1994) and other articles in the same journal issue). On the policy arena a renewed interest in integrated land-use/transport models has emerged from the growing importance of environmental issues. In the US, the Clean Air Act of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991 provide new challenges for development of policy responsive and integrated land-use and transport modelling. The focus on sustainable development and Agenda 21 during the 1990s has also led to a demand for integrated analyses of social, economic and environmental urban and regional problems. A few examples of policy discussions related to sustainability will be provided but a thorough treatment of sustainable development is outside the scope of this paper.

In Sweden a new national transport policy was adopted in 1998: Transport Policy for a Sustainable Development. Its main objective is to provide citizens and firms in all parts of the country with a transport supply that is socio-economically efficient and sustainable in the long term. Six sub-goals are formulated: an accessible transport system, high transport quality, safe traffic, good environment, positive regional development and equality between genders. Two of these have very precise and rather far-reaching short term objectives: the number of persons killed in traffic accidents should be reduced by 50% 1996-2007, the emission of CO_2 from transport should not increase 1990-2010 and the emissions of NO_x, S and VOC from transport should be reduced by 40%, 15% and 60% respectively in the period 1995-2005.

In the committee report preceding the new national transport policy (Communication Committee, 1997), one chapter was devoted to “a less transport intensive society”. In addition to the economic incentives and regulations for internalising the external costs of transport, the committee emphasises that a better co-ordination between the planning of settlements, infrastructure and traffic is needed. In particular, a public transit oriented development of land-use is discussed. A stronger position for regional planning is required which may develop from a stronger regional role in the distribution of resources for infrastructure investments. It is also noted that Agenda 21 requires an integrated land-use and transport planning. Guidelines for such an integration have been adopted in Norway, in the UK and in the Netherlands. These principles are said to be applicable also in Sweden. However, the committee proposes no formal guidelines, partly because of differences in the planning system with a stronger role for local governments in physical planning in Sweden. The existing Planning and Building Code is containing guidelines that can be given similar interpretations as the guidelines in Norway and in the UK. Also in the area of external locations of shopping centres, the committee considers the existing planning regulations to be sufficient for the time being. Local governments should be restrictive in permitting new external centres that can weaken the position for city centres and local services.

The emphasis on sustainable development during the 1990s has lead to a discussion of integrated policies (e.g. land-use/transport policies) in many countries. At the European level, an EU Directive on Strategic Environmental Assessments (SEAs) of certain plans and programmes was adopted in 2001, EU (2001), in order to take environmental issues into account at an early planning and programming stage. Similar strategic economic and social impact assessments are also emerging. The message from many policy discussions on sustainable urban development has been clear: increase densities, promote a mix of land-uses, cluster high density, walking scale settlements along public transport lines. Peter Hall (1997) has noted the similarity between these principles and the ones underlying the General Plan of Stockholm in 1952 with its satellites located on underground transit lines. Economic developments and behavioural changes (income, car ownership, commuting patterns, modal choices, housing demand, etc) have resulted in a less sustainable urban region than initially intended, although in relative terms Stockholm is considered to be sustainable in a European or, even more so, in an American context. It can be concluded that a proper account of the interplay between socio-economic mega trends, land-use and transport planning and developments on urban markets are essential for achieving a sustainable development. There is a wide range of options for reorganising the use of existing land-use/transport systems without major rebuilding of urban infrastructures. However, in order to study such options a comprehensive systems view of urban interactions is needed. Land-use/transport models may have a role to play in assessing the impact of package policies for urban management on indicators of urban sustainability.

3. Some results from studies of land-use and travel behaviour in the Stockholm region during the last decade

In this Section some long-term results from the early preparatory stages of the work on the Regional Development Plan 2001 for the Stockholm region are reported. A related study conducted by the City of Stockholm illustrates the kind of planning and management measures that are likely to be needed in order to achieve long term environmental goals. Finally, some projections related to the consultation proposal in connection with the Regional Development Plan 2001 are presented.

During 1995 a number of interrelated long-term studies were carried out in the Stockholm region. They were based on an integrated traffic forecasting system (traffic demand model T/RIM and traffic assignment model EMME/2) and on a related land-use/transport model system (IMREL). The studies were commissioned by the County Council Office of Regional Planning and Urban Transportation and the Stockholm City Planning Office.

In the report "Traffic and Environment – Studies of Regional Structures", the County Council Office of Regional Planning and Urban Transportation (1995) analysed five scenarios for the land-use/transport system until the year 2020. The scenarios differ with respect to investments in the public transport and road networks and with respect to the pattern of land-use development. Four of these scenarios are subject to more detailed comparisons in Table 3. One of the five scenarios is representing the adopted Regional Plan 1991. In Table 1 the results for the Regional Plan scenario and the intervals obtained for the five scenarios are reported. The results for 1993 are also produced by the model.

Table 1. Regional structures: long-term projections of traffic and environment

Scenario	1993	RP91/2020	Five scenarios/2020
Traffic[a]:			
Person kilometres[b]	4712	5877	5862-6852
VKTc, County	1916	2839	2666-2862
VKT[c], Inner city	139	141	128-145
Transit share (%)	39	34	34-38
Emissions (tons):			
Carbon dioxide	503	758	716-768
Nitrogen oxides	5.72	2.58	2.44-2.63
Hydrocarbons	5.78	0.78	0.74-0.79

[a] Morning peak hour indicators
[b] Thousands
[c] Vehicle kilometres of travel (thousands)

Source: Office of Regional Planning and Urban Transportation (1995)

The projected traffic volumes for the county imply a traffic growth of around 50% during 1993-2020. For the inner city the traffic volume is stabilised on the 1993 level by the introduction of a cordon toll system that was part of the transport system according to the Regional Plan 1991. The RP91 scenario leads to a growth of vehicle traffic that is on the high side as compared to the other four scenarios. This is due to the long-term drop in the transit share by 5% in the RP91 scenario, while in the transit oriented scenario the transit share remains almost stable. The emission forecasts show good improvements in terms of nitrogen oxides (about 55%) and hydrocarbons (about 87%). However the emissions of carbon dioxide are projected to increase by about 50%, which should be compared to the intermediary transport policy target of –15% (1990-2020). The assumptions concerning increased fuel efficiency seem to have been very modest.
These conclusions are reinforced by another long-term land-use/transport scenario study conducted by the Stockholm City Planning Office (1995), "A Sustainable Transport System for the Stockholm Region – Scenario Studies". The impacts of combined scenarios for economic growth, vehicle technology and land-use/transport policies were studied for the period 1993-2020. The base scenario is identical to the adopted Regional Plan of 1991. Additional scenarios are formed by accumulated changes: 1. Extensive increase in transit supply, 2. No eastern and western by-passes (i.e. elimination of two major road investments), 3. Higher land-use density (i.e. more development in the central part of the region), 4. Doubled cordon tolls, 5. Doubled fuel prices. The results are summarised in Table 2. A comparison is made between the reference scenario, the accumulated impacts of changes in transport networks and land-use (Scenario 3) and the accumulated impacts of infrastructure and pricing policies (Scenario 5). The ranges are reflecting economic growth and vehicle technology scenarios.

Table 2. A sustainable traffic system for the Stockholm region: scenario studies

Scenario	1993	RP91/2020	Scenario 3/2020	Scenario 5/2020
Traffic:				
VKT[a], County	100	120-150	108-136	86-108
Emissions:				
Carbon dioxide	100	30-129	27-116	21-91
Nitrogen oxides	100	28-52	25-47	20-37
Hydrocarbons	100	11-22	10-21	8-15

[a] Vehicle kilometres of travel

Source: Stockholm City Planning Office (1995)

Obviously, the most optimistic vehicle technology assumption together with moderate economic growth will make possible drastic reductions of emissions (70-90% in comparison with 1993). As can be seen by the difference between Scenario 3 and the reference scenario (RP91), only a minor part of these reductions is related to land-use/transport policies (12-14 index points, or about 35%, in terms of VKT and similar shares in terms of emissions). User charges are more important (compare Scenario 5 with RP91). However the assumptions on vehicle technology are by far the most influential factor for the level of emissions, followed by the assumptions on economic growth. For meeting the strict long-term objective concerning the reduction of carbon dioxide (80% reduction of the 1993 level), a very optimistic scenario for vehicle technology is required (in combination with moderate economic growth and implementation of all infrastructure and pricing policies). This also leads to fulfilment of the other environmental targets.

The influence of land-use and transport systems on traffic indicators can be further illustrated by some results from "Traffic and Environment – Studies of Regional Structures". In Table 3 three land-use/transport scenarios for 2020 are compared to the reference scenario, i.e. the adopted Regional Plan 1991: 1. A regional structure with higher density, transport systems according to the Regional Plan (Dense/RP91); 2. A dispersed but transit-oriented settlement pattern, doubled transit supply, no eastern and western ring road by-passes (Corridor/Road min); 3. Very dispersed settlement pattern, doubled transit supply, no eastern and western ring road by-passes (Dispersed/Road min). The land-use differences between the scenarios are shown in Table 3 in terms of sub-regional shares of new housing developments 1990-2020 as compared to the total shares of the housing stock in 1990.

Table 3. Regional structures: impact of land-use/transport systems 2020

Scenario	1993	RP91 RP91	Dense RP91	Corridor Road min	Dispersed Road min
Housing (share of new development):					
Inner city	57[a]	38	52	21	13
Inner suburb	18[a]	22	35	17	12
Outer suburb	15[a]	24	6	39	51
Periphery	10[a]	15	5	25	25
Traffic[b]:					
VKT[c], County	1916	2839	2799	2666	2862
VKT[c], Inner city	139	141	145	131	134
Person kilometres[d]	4712	5877	5862	6681	6852
Transit share (%)	39	34	34	38	37
Average trip length[e]	13.3	12.5	12.4	13.9	14.3

[a] Share of total housing in 1990
[b] Morning peak hour indicators
[c] Vehicle kilometres of travel (thousands)
[d] Thousands
[e] Kilometres

Source: Office of Regional Planning and Urban Transportation (1995)

Higher density of urban development does not have any major impact on the traffic indicators as compared to the Regional Plan (which is already fairly dense). On the other hand, for a very transit oriented transport system the difference between land-use alternatives oriented towards transit corridors or dispersal is considerable. One may conclude that the land-use distribution within sub-regions tends to be more important for the traffic conditions than the land-use distribution between sub-regions.

The studies reported above have shed some light on how land-use changes might impact on transport behaviour. The reverse impact on land-use of an extensive transport policy proposal was subject to analysis in Stockholm in the beginning of the 1990s, see Johansson and

Mattsson (1995). The transport policy proposal, containing both road and transit investments and cordon tolls (the so called Dennis agreement), was compared to a do-nothing scenario. The model projection indicated a decentralisation of land-use with about 25000 residents and 25000 workplaces being relocated at a 99-zone subdivision of the Stockholm region. This corresponds to 1.3% and 2.3% of the total activity amounts.

The consultation proposal for Regional Development Plan 2001 for the Stockholm region is summarised in Table 4. Two land-use alternatives were presented with various degrees of relative decentralisation until the year 2030. The shares of development (population and employment) in the inner city and the share of population in the inner suburbs are decreasing in both cases. The traffic implications are reported for two economic growth scenarios and for one common transport network scenario. The reduction of the transit share is projected to continue in spite of increased transit supply and shorter average transit travel times. The reduction is somewhat more pronounced in the dispersed settlement pattern. The vehicle kilometres of travel and person kilometres of travel are rapidly expanding. Introduction of a toll system will reduce the total VKT by about 4 index units and the VKT in the inner city by about 15 index units. The emissions of CO_2 per capita from transport are projected to increase by 10-15% during 1997-2015, which obviously is in conflict with the adopted national (and regional) targets.

Table 4. Regional structures and transport patterns 2030

Scenario	**1997**	**2000 Pop**	**1995 Emp**	**2030 Concentrated**		**2030 Dispersed**	
				Pop	**Emp**	**Pop**	**Emp**
Inner city[a]		279	286	315	341	279	275
Inner suburb[a]		627	263	785	406	684	337
Outer suburb[a]		491	151	674	229	752	335
Periphery[a]		423	139	615	237	675	266
Traffic[b]:				**High[e]**	**Base[e]**	**High[e]**	**Base[e]**
Number of trips:							
Car	148			260	206	274	212
Transit	168			210	202	197	195
Bike/Walk	84			94	85	93	85
Transit share (%)	42			37	41	35	40
VKT[c], County	100			158	135	166	139
VKT[c], Inner city	100			136	121	126	115
Person km[c], car	100			161	136	170	140
Person km[c], transit	100			126	118	120	115
Av. tr. time[d], car	20,9			20,4	20,2	20,1	20,1
Av. tr. time[d], transit	38,0			31,7	31,3	31,9	31,5

[a] Thousands
[b] Morning peak hour indicators
[c] Index 1997=100
[d] Minutes
[e] Scenarios for economic development

Source: Office of Regional Planning and Urban Transportation (2000)

In summary, Stockholm is moving in the eastern or north-eastern direction in the Brotchie diagram (Figure 2). This development is characterised by a decreasing transit share, increasing amounts of vehicle kilometres of travel and dispersal of land-uses. Only a very drastic combination of land-use/transport policies, development of vehicle technology and economic incentives can reduce greenhouse gases to the long term target of 20% of the 1990 level and stabilise the total vehicle kilometres of travel (VKT) according to Stockholm City Planning Office (1995), see Table 2. Land-use and transport network changes may reduce VKT by 12-14 index points (about 10%) as compared to the base scenario, while economic incentives (doubling of tolls and petrol prices) is projected to further reduce the VKT by 22-28 index points (about 20%). Of the 10% reduction due to land-use and transport network changes, the higher density of land-use contributes with only 2-3% while increased transit supply and reduced road capacity cause a 7-8% reduction. A bigger land-use effect might have been obtained by using the "corridor" scenario instead of the "dense" scenario, compare Table 3. The impact of lower economic growth rate (0.9% annual growth of the household disposable income instead of 2.0%) is a reduction of VKT by about 20%. Assumptions concerning vehicle technology are most important for the projected level of emissions, in particular for CO_2 emissions.

4. Some results from international studies of urban land-use and travel behaviour

In a very interesting paper, Wegener (1996) discusses the conventional wisdom of recommending increased density and mixed land-uses to handle environmental problems of urban areas (see e.g. the Green Paper on the Urban Environment of the European Communities). He refers to research results, which indicate that "decentralised concentration" tend to be the most energy conserving urban form. The famous relationship between urban density and per capita petrol consumption (Newman and Kenworthy, 1989) is reinterpreted in terms of a relationship between normalised petrol price and per capita petrol consumption. The outcome indicates that urban density may be an intermediate variable affected by the more fundamental differences in petrol price.

Wegener then proceeds to carry out a case study of the Dortmund region by using an integrated land-use/transport model. A number of future scenarios for travel costs and travel speeds are compared to a base scenario (business-as-usual). In particular two combination scenarios are formulated: "promotion of public transport (PPT)" and "reduction of mobility (RM)". Very drastic increases of petrol prices (increased four times 1995-2015) and inner-city parking costs (increased five times) are contained in both these combination scenarios. In addition the PPT scenario includes making public transport faster and cars slower, while in the PM scenario both public transport and cars were assumed to be slower and, moreover, public transport fares were assumed to double. The PPT scenario resulted in a reduction of VKT by more than 50% 1995-2015 while the base scenario would result in a 25% increase. The observed decay of the public transport share from about 31% 1970 to about 17% 1995 could be reversed into a projected growth to about 40% 2015. CO_2 emissions from transport were projected to decrease by about 65% 1995-2015 and reach a level considerably lower than in 1970. Most scenarios result in moves in the north-eastern direction of the Brotchie

diagram (more dispersal of land-use and more travel). The PPT scenario leads to increased density (less dispersion of both residences and working places). Working places respond more strongly to transport changes than residences according to the model.
The overall conclusion of Wegener (1996) is that there is a wide range of options for reorganising the utilisation of spatial structures that may lead to significant reductions of energy use and CO_2 emissions without substantial land-use changes, without unacceptable losses of mobility and without widening social disparities. It should be kept in mind that the simulated price increases are much more drastic than the ones used in the Stockholm scenario study (compare Table 2) and the simulated impact on VKT is also much stronger.
In a recent survey of empirical studies of land-use/transport interactions in North America, Badoe and Miller (2000) discuss both the impact of urban form on travel behaviour and transit impacts on urban form. Their summary concluded that the role of residential density as a determining factor for transit usage as well as for the use of non-motorised modes is unclear. The impact of residential density as a direct explanatory variable declines significantly when other factors (e.g. socio-economic characteristics, accessibility) are introduced. Concentration of employment seems to have a stronger and more consistent influence on transit usage, walking and ride-sharing. More emphasis on employment location and on location of other out-of-home activities in modelling and policy-making seems to be the natural implication. Accessibility is a key factor in analysis of relationships between land-use and transport. Investigations of the impacts of local access to work opportunities (i.e. job-housing balance) on VKT have lead to mixed findings. Finally, studies of impacts of neighbourhood design on travel behaviour also show quite mixed results. Neighbourhood design is important for densities, ease of walking and for provision of transit services, but the complex interaction patterns of modern societies extend far beyond the local neighbourhoods and are related to the overall functioning of the land-use/transportation systems of the urban area.
Other examples of recent studies of relations between land-use contexts and travel behaviour are reported in Schwanen et al. (2001, 2002). The impacts of contextual and individual attributes on travel distance and travel time are analysed on the basis of the Dutch national Travel Survey. De-concentration of urban land-uses is found to encourage car travel at the expense of other modes. In terms of average distance travelled, the results of de-concentration are mixed.
Reference can once again be made to the Brotchie triangle (see Figure 2) illustrating the ranges of travel behaviour options in a certain urban form (degree of dispersion). Proximity and travel costs are weighted against the utility of interactions in determining travel behaviour. Complex labour markets and high evaluation of variety in consumption and activity patterns may lead to longer trips in a city with locally balanced neighbourhoods than in a city with high concentration of employment and services in the city centre. The general conclusion of Badoe and Miller (2000) is a strong plea for integrated land-use/transport models in order to analyse interactions between urban form and travel behaviour and between transit supply and urban form in a comprehensive way. The ambiguities of some of the earlier studies might have been caused by the use of partial approaches, omitting important variables and important linkages.
The European Conference of Ministers of Transport (1995) also notes the rather weak effectiveness of land-use planning in limiting car usage and the need for integrating land-use and transport policies. The potential contingency value of urban forms offering possibilities

for shorter trips in a situation with dramatically higher fuel prices is emphasised, even if the current use of such urban forms may lead to diffuse patterns of car journeys (Figure 2 is referred to again).

5. Transport, land-use and regional development – some observations on redistribution and economic development effects

Although the main interest in this analysis is devoted to relations between land-use and travel behaviour on the urban level, we will briefly comment on the relations between transport initiatives on the one hand and land-use or regional development on the other hand.

Badoe and Miller (2000) note the difficulty in isolating the effects of transit supply on urban form. Land-use effects materialise slowly and many other changes occur simultaneously, which also affect land-use. For identifying the "true" land-use effects of a transport supply change, an integrated land-use/transport model would be needed in combination with a before-and-after database.

Using such an integrated land-use/transport model, large transport policy programmes (e.g. the Dennis proposal in Stockholm and a system of regional trains) have been projected to result in redistribution of less than 5% of the population and working places between 214 zones (mainly in the decentralising direction) in the Mälar Valley, which represents a major extension of the Stockholm region. On a larger interregional scale the corresponding redistributions between counties have been projected to be smaller, below 1%, see Anderstig and Mattsson (1998).

The transport networks of developed economies are characterised by high density of links and good accessibility standards. Single transportation improvements tend to have only marginal impacts on the accessibility pattern and hence lead to marginal land-use or regional development effects. Investment programmes or package policies may lead to re-distributions of activities to the extent mentioned above. The net effect (to be distinguished from the re-distributional effects) on economic activities (production or productivity) of infrastructure improvements is an issue that has been subject to much controversy in the recent decade. In developed networks the elasticity of production with respect to transport infrastructure is found to be small (<0.06), corresponding to a normal rate of net return (this would indicate that the transport infrastructure is of the right size). The need to consider productivity effects in addition to the outcome of traditional CBA analysis has also been discussed. In Communication Committee (1997) the potential productivity effect in addition to conventional ("on the road") CBA analysis was estimated to less than 20%. If the CBA analysis is based on sophisticated regional-economic modelling (e.g. Spatial Computable General Equilibrium Modelling) the need for corrections would be smaller since impacts on transport generation, location and integration of labour markets would have been endogenised.

Historically developed relationships between accessibility and the level of economic activities can be observed. It is more difficult to find clear relations between changes in accessibility and changes in the level of economic activities. Due to the "two way road" effect a transport improvement to a region might lead to negative effects depending on the relative competitiveness of the economy of this region as compared to the region(s) at the other end of the road. The role of transport supply as a necessary but not sufficient condition for economic development or land-use development has been highlighted in many studies (e.g. Badoe and Miller, 2000). Other policies (e.g. land-use, education, economic climate) need to interact in a mutually reinforcing way for development effects to occur. Such synergies between policies are important to analyse. Combined land-use and transport policies have been advocated strongly (e.g. The European Conference of Ministers of Transport, 1995).

6. Conclusions

The growing importance of policies for a sustainable development of urban areas has lead to a renewed interest in integrated land-use/transport interactions and modelling. Schemes for illustration of interactions between urban land-use and transport behaviour and for comparative analysis of urban systems have been suggested.

The conventional wisdom of recommending a high density, mixed land-use “compact city” with a clustering of settlements along transit lines has strong similarities with the principles behind the Stockholm General Plan 1952 with dense satellites located on underground lines. Economic and behavioural changes have lead to a less sustainable use of this structure than initially intended with a high degree of car use and a high degree of out-commuting from the satellites. This is in line with the observation that most cities are moving towards decentralisation of population and employment and increasing VKT.

Future scenarios for the Stockholm region show that, in addition to an assumption of moderate economic growth rate, fairly drastic measures have to be taken in order to stabilise VKT over a 30-year period, including public transport investments, land-use policies and strong economic incentives in favour of public transport. The separate impact of higher land-use density only accounts for about 10% of the overall reduction of VKT as a result of infrastructure and pricing policies. In other scenarios it is shown that a sub-regional transit-oriented land-use policy is more important for retaining a high transit share than the overall density on a regional scale.

With even more drastic economic incentives and transport policies, model projections for Dortmund show that there is scope for much reorganisation within an urban region implying reversals of the decreasing transit share and of the increasing VKT. The “promotion of public transport” scenario is leading to a somewhat higher density than other scenarios.

Employment location and employment densities tend to have stronger impacts on travel behaviour than residential densities. Employment has also shown to be more responsive to transport changes than housing.

In highly developed economies the impact of transport infrastructure improvements on land-use and regional economic development can be expected to be small and masked by other simultaneous changes. Due to the “two way road” effect the impact of a transport improvement can even be negative to a region. Transport supply is a necessary but not sufficient condition for development of land-use or of the regional economy.

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